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# PROCESS FOR THE CONDITIONING OF LIQUEFIED NATURAL GAS

This invention relates to a process for conditioning liquefied natural gas.

Liquefied natural gas (LNG) needs to be vaporized before being fed into a pipeline for distribution. In a typical vaporization process, the LNG is fed into a tank. This inevitably results in some gas vapour loss; typically this off-gas is compressed and then passed to a boil-off condenser where it is condensed, for example by passing a quantity of LNG from the tank into the boil-off condenser where the boil off gas, at increased pressure, is combined with the LNG stream to produce an all-liquid stream which may be passed back into the tank or combined with an outflow stream from the tank. LNG is then passed from the tank to a pump which discharges the LNG, at a suitable pressure, to a pipeline, via one or more heat exchangers which vaporize the LNG.

However, in many cases, the LNG does not meet required product or pipeline specifications because of the presence of excess quantities of hydrocarbons containing two or more carbon atoms, and various additional processing steps are required.

GB 1,185,053 discloses a high pressure process for obtaining a fluid rich in methane from LNG. The high pressures used lead to high engineering and operating costs. Fig. 1 shows a column which is fed by a pump which subjects the feed stream to the column to a pressure of 25 bars absolute, which means that the column must be engineered to operate at a pressure of close to 25 bars absolute.

US 6,604,380 is also a high pressure process, with a pump raising the pressure of the LNG to 100-500 psig, preferably the process range of 300-350 psig. The scheme is complex, initially splitting the feed stream into at least two parts, with at least one part being used as a reflux stream to a packed column.

US 2003/0158458A1 discloses a scheme for separating methane-rich and ethane-rich components from an LNG stream, which includes a separator and a column. Fig. 1 shows the feed stream being passed direct to the column 28, which is operated using a reflux pumped from the separator 24. In effect, the separator acts to recycle the gas stream from the column, and therefore only part of the LNG feed is subject to that separation.

US 6,564,579 describes a process for the removal of natural gas liquids, typically hydrocarbons containing two or more carbon atoms, from LNG, in order to provide a product with a reduced heating value which meets pipeline or other commercial specifications. This process, which is of a type which may be referred to as conditioning, includes the following steps: vaporizing at least a major portion of a stream of the liquefied natural gas to produce an at least partially vaporized natural gas stream; fractionating the at least partially vaporized natural gas stream to produce a gas stream and a natural gas liquids stream; compressing the gas stream to increase the pressure of the gas stream by about 50 to about 150 psi to produce a compressed gas stream and cooling the compressed gas stream by heat exchange with the stream of liquefied natural gas to produce a liquid compressed gas stream; pumping the liquid compressed gas stream to produce a high-pressure liquid stream at a pressure from about 800 to about 1200 psig; vaporizing the high-pressure liquid stream to produce a conditioned natural gas suitable for delivery to a pipeline or for commercial use; and recovering the natural gas liquids.

The process of US 6,564,579 provides a number of advantages. However, the process has itself a number of significant disadvantages. In particular, a preferred embodiment of the process as shown in figure 5 of US 6,564,579 requires the use of a high-pressure distillation vessel (38 in figure 5); thus, according to column 7 lines 15-30: "The overhead gas from the separation vessel 86 is passed via a line 94 to compression in a compressor 50 wherein the pressure is increased by approximately 50 to 150 psi. The pressure in line 54 after compression in compressor 50 is typically from about 100 to about 300 pisg. This enables the return of the gas from tank 86 via line 54 to heat exchanger 34 for liquefaction. The liquids recovered from separator 86 are passed via a line 88 to a pump 90 from which they are passed via a line 92 to distillation vessel 38. Distillation vessel 38 functions as described previously to separate NGLs, which are recovered through a line 46, and to produce an overhead gas stream, which

comprises primarily methane. This gaseous stream is recovered through a line 48 and is passed to combination with the gas stream in line 54. The combined streams are then liquefied in heat exchanger 34." Because the pressure in line 48 must be the same as the pressure in line 53, column 38 must be operated with a gaseous outlet pressure of 100 to about 300 psig. This means that the liquid stream from 86 must be pumped (via pump 90) to column 38.

We have now found a simplified process for the conditioning of LNG which can be operated more efficiently and cheaply than the processes of the prior art.

Accordingly the present invention provides a process for the conditioning of liquefied natural gas, which comprises applying the following steps to a feed stream of liquefied natural gas:

i. vaporizing at least a major portion of the feed stream of liquefied natural gas to produce an at least partially vaporized natural gas stream;

ii. separating the at least partially vaporized natural gas stream to produce a first stream which is rich in methane and a second stream which is rich in hydrocarbons having two or more carbon atoms;

iii. if required, compressing the first stream from step (ii) to increase the pressure and produce a compressed gas stream;

iv. cooling the compressed gas stream from step (ii) or (iii) by heat exchange with at least part of the feed stream of liquefied natural gas to produce a liquid compressed gas stream;

v. passing the second stream from step (ii) without pumping to a distillation vessel to produce a natural gas liquids stream and a stream rich in methane, the operating pressure of the distillation vessel being such that the stream rich in methane exits the distillation vessel at a pressure in the range of from 2 to 6 barg;

vi. cooling the stream rich in methane from step (v) by heat exchange with at least part of the feed stream of liquefied natural gas and subsequently pumping to produce a liquid compressed gas stream;

vii. optionally combining the liquid compressed gas streams from steps (ii) or (iii) and (vi);

viii. vaporizing the liquid compressed gas streams from steps (iv), (vi) and/or (vii) to produce a conditioned natural gas; and

ix. recovering the natural gas liquids.

The process according to the invention produces a conditioned natural gas which is suitable for delivery to a pipeline, or for other commercial use, together with natural gas liquids. In general, the natural gas liquids comprise hydrocarbons having 2 or more carbon atoms. If desired, the initial natural gas liquids product obtained by the process of the invention can be further processed, for example by the removal of ethane in a deethaniser column.

Preferably in excess of 90% or 95% of the feed stream to the process, preferably all of the feed stream, is fed to step (i) of the process. If desired, a small quantity of the feed stream may be used to perform certain functions within the process, for example to cool a compressor. It is however an advantage of the process according to the invention that none of the feed stream is required to act as a reflux in columns used in the process, unlike the process of US 6,604,380, in which part of the incoming cold LNG bypasses the vapourising heat exchanger and is used as reflux in the column 22 and possibly the separator 20.

Preferably the separation of step (ii) is carried out using a separator which contains a minimum of internal structure. No reflux streams are necessary, and therefore no packing materials or gas-liquid separation trays are required, although if desired the separator may contain one or more knit-mesh structures to assist in removing entrained liquids.

The output from step (ii) comprises two separate streams, a gas stream and a liquids stream. The gas stream is compressed if necessary in optional step (iii) (whether this is necessary will depend upon the operating pressure of the fractionation step (ii)) and sent to a heat exchanger where, in step (iv), it is cooled against the LNG feed stream. The liquids stream is separated into a natural gas liquids stream and a gas stream in the distillation vessel of step (v), which vessel contains gas-liquid separation packing or trays to provide vapour-liquid contact. Said vessel does not require the presence of a reflux stream; specifically, it does not require the presence of a cold LNG reflux stream obtained from the feed stream to the process.

The gas stream resulting from step (v) is sent to a heat exchanger where it is cooled against the LNG feed stream (step (vi)). It is an important feature of the process of the invention that the gas streams from steps (ii)/(iii) and (v) are at different pressures from each other and are therefore cooled in separate streams. The heat exchange on these

two streams may be carried out using different heat exchangers, or it may be carried out using a multi-stream heat exchanger. Preferably the heat exchanger(s) used is a plate-fin exchanger; these are very compact, and tighter temperature approaches are possible.

Following the heat exchange of steps (iv) and (vi), the gas stream originating from step (v) may be compressed to equalise its pressure with that of the higher-pressure stream originating from step (ii)/(iii), and the two streams may be combined prior to pumping to further increase the pressure, followed by vaporization to produce the desired conditioned natural gas.

The process of the present invention provides a number of advantages relative to the process described in Figure 5 of US 6,564,579. Because there is no requirement to merge two separate gas streams prior to heat exchange, the distillation vessel used in step (iv) operates at a relatively low pressure, the exit stream rich in methane being at a pressure in the range of from 2 to 6 barg, preferably from 3 to 5 barg (in contrast to the column of Figure 5 of US 6,564,579 which operates at a relatively high pressure, the exit stream being at 100 to 300 psig, equivalent to 6.9 to 20.7 barg). The liquid stream from step (ii) may therefore be let down into the distillation vessel: no pump is required to transfer the natural gas liquids stream from step (ii) to the distillation vessel, and the process is thereby simplified. The compressor used to compress the gas stream exiting from the distillation vessel in step (ii) can be used at a lower pressure differential. Importantly, the distillation vessel may be reboiled using seawater rather than steam which is required for the reboiling of higher pressure vessels, although steam may be used if desired. And finally, keeping the gas streams from steps (ii)/(iii) and (v) separate rather than combining them prior to heat exchange may improve the heat recovery efficiency, especially if a plate-fin heat exchanger(s) is used.

The process of the invention may be integrated with existing LNG handling facilities. The process may also form part of an integrated energy recovery system as described in US 6,564,579.

The invention is further illustrated in the accompanying drawing, in which the figure illustrates a flow scheme which represents the process according to the invention.

A tank 1 contains LNG forming the feed to the process. Tank 1 is typically a cryogenic tank. An in-tank pump 2 pumps the LNG from tank 1 via a pump 3 which increases the pressure typically to around 9 to 13 barg. From the pump 3 the LNG is passed to a multi-channel heat exchanger 4, preferably of the plate-fin type. A line 5

carries the LNG to a separation vessel 6 having two outlet lines and a minimum of internal structure. Outlet line 7 carries a gas stream from the separation vessel 6 to a compressor 8 where the pressure is increased typically by from 2 to 5 bar, for example around 3 bar. A line 9 feeds the resulting compressed gas stream back to one channel 30 of the multi-channel heat exchanger 4. Outlet line 10 carries a liquid stream from the separation vessel to a distillation vessel 11 containing gas-liquid separation packing or trays to provide vapour-liquid contact, which separates the input stream into a liquid stream comprising natural gas liquids which are removed via line 12, and a gas stream which is removed via line 13 and fed back to the multi-channel heat exchanger 4 using a separate channel 31 from that used by line 9. The pressure drop across distillation vessel 11 is such that pressure of the gas stream removed via line 13 is in the range of from 2 to 6 barg.

The distillation vessel 11 is provided with a reboiler 20 comprising a heat exchanger 21 and a line 22 forming a closed loop back to the distillation vessel 11.

The stream exiting channel 30 is carried by line 14 typically at a pressure of from 12 to 16 barg to mixing point 15. The stream exiting channel 31 is carried to a pump 16 where its pressure is equalised to that of the stream exiting channel 30 before being carried to mixing point 15 where it is combined with the stream exiting channel 30. The combined streams are then passed to pump 17 and subsequently vaporised in heat exchanger 18 before being discharged into a pipeline.

The whole process is carried out at normal cryogenic temperatures, for example, the feed stream of LNG is typically at a temperature of around -170 to -150°C, the temperature at each point in the process depending upon the pressure.

The exact temperatures and pressures used will naturally depend upon the exact set-up details of the process. Various modifications of the flow scheme shown in the figure are likewise possible. For example, pump 3 may be omitted if the LNG feed stream is at a sufficiently high initial pressure. An additional pump may be added to line 5 if it is desired to run the system at a higher pressure. Multi-channel heat exchanger heat exchanger 4 may be replaced by two separate heat exchangers, with a corresponding rearrangement of the LNG feed stream.